On forest ecosystem health and its Connotations

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Abstract: This paper cursorily introduced some ideas and approaches of ecosystem health researches. The definition and connotations of forest ecosystem health have also been expatiated. Defining forest ecosystem health has been discussed from the management objective approach, ecosystem approach, and integration approach. To impel the relative researches in China, more attention on the properties of a forest ecosystem should be paid.

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Introduction

One of the great contributions of natural science in the 20th century was the further cognition of the relationship between human being and nature. Human being is only a part of nature, not a dominator. Ecosystem health, as a new thought and a new method environmental management and sustainable development, provides us some hopes when facing environmental and ecosystem degradation (Callicott 1992; Costanza 1992). A Healthy ecosystem is not only the object and result of ecosystem health study but also a criterion of measuring ecosystem structure and function. It is necessary to harmonize the natural ecosystem with social, economic, and human needs. Forest ecosystem is a main ecosystem on the Earth and plays an important role in human survival. Since the self-maintained physical environment of forest ecosystem becomes a resource, an alluring resource for human, all forests on the Earth suffer lightly or heavily from damages of human activities (cutting, land use, fire, timbering, etc.). Healthy forest ecosystem is regarded as the basis of healthy human, healthy society, and regional sustainable development. Improper understanding of forest ecosystem may lead to some false behaviors or directly destroying forest. Thus, exactly understanding the meaning and connotations of forest ecosystem health is a key for human activities on how to treat the remained forest and make sustainable use of forest resources.

Rise of ecosystem health study

Ecosystem health study began in 1940s, Aldo Leopold defined "Land Health" and described soil dysfunction in 1941 (Callicott 1992, 2000; Covington *et al.* 1997; O'-Laughlin-J *et al.* 1993; Rapport *et al.* 1998). Up to 1980s, the ecosystem health had become a comprehensive subject of nature science, social sciences, and human health. In 1988, Schaeffer *et al.* primarily studied the measurement of ecosystem health (Schaeffer 1988). Rapport *et al.* (1998) dissertated connotations of ecosystem health. In January of 1991, the International Moral Society held a workshop of "Define ecosystem from the aspects of nature, economic and moral". Since then, some international societies about ecosystem health have been founded, meantime, a series of journals about ecosystem health have been published, such as *Journal of Aquatic Ecosystem Health* (renamed as "Journal of Aquatic Ecosystem Stress and Recovery" in 1997) and *Ecosystem Health* .

Ecosystem health study has been conducted in various ecosystems, and quite a few definitions and ideas of the ecosystem health have come forth. As an endpoint of environment management and basis of sustainable development, ecosystem health is considered as a capability or condition of ecosystems that ensures their well-balanced ecological services and sustains their complexity and development while providing for human needs, maybe, for the stressed ecosystems; health is a goal, an ideal point need to restore (Covington *et al.* 1997).

Definitions of forest ecosystem health

Although forest ecosystem health (forest health) is a relatively new term in forestry (Alexander *et al.* 1999; Craig 1994; Lankford 1994), it has been increasingly used in many papers of forestry and natural resource management in the recent ten years, even in some political reports and plans, particularly in USA, the advanced area of forestry intensive management. The early use of this term mostly refers to the declining phenomena of forest, such as defoliation before mature, canopy thinning, discolor, leaf curling, large-area forest death, and threaten of plant diseases and insect pests (Alexander *et al.* 1999; Covington *et al.* 1997; Raddip 1992; Richard *et al.* 1997). Many researches of forest health conducted were aimed at direct changes of

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stressed forest, and the study scope was expanded from individual to region, or nationwide. In 1992, USA Congress constituted "forest ecosystem health and restoration law", and a series of evaluation reports and monographs was published in 1993 (Steedman 1994). In these reports and books, it was commonly recognized that forest ecosystem health is a condition of forest ecosystems that sustains their complexity while providing for human needs.

Now the concept of the forest ecosystem health has the following understandings: forest management objectives, forest ecosystem function, and integrated perspective (Alexander et al. 1999; Kolb et al. 1994).

Forest management objective: More attentions have been paid to the utilization of forest resources by government, private landowners, and some forest consultants who hoped to get more benefits (timber, edible mushrooms, etc.) through sound management of forest resources. They take the achievement of their objectives as the standard of the definition of Health. From this view, a desired state of forest health can be considered as "a condition where biotic and abiotic influences on forests (e.g., pests, pollution, silvicultural treatments, harvesting) do not threaten management objectives now or in the future". That is, a forest is considered to be healthy if management objectives are satisfied or unhealthy if the management objectives are not satisfied. "Consistency with objectives" is a central theme in many objective-oriented definitions of forest ecosystem health. USDA Forest Service defines the forest ecosystem health as "an unhealthy forest inhibits managers from achieving objectives; a healthy forest does not pose such obstacles." It follows that a healthy forest may not be insect-free or pathogen-free, but sufficiently free of pest damage to meet management objectives. Some non-industrial private forestland owners said: "forest ecosystem health is a condition that optimizes the landowner's opportunity to achieve management objectives" (Craig 1994; Lankford 1994). Such a state is the product of ecologically sound management, which varies with the intent of owners. Thus, forest health is determined by objectives, and ecologically sound management is the best means to achieve it.

Considering whether a forest is healthy or not, we need to discuss the following questions: (1) Management to achieving objectives requires a clear and explicit statement of these objectives so that the managers know whether they are on target to meet the objectives; (2) objectives must reflect limitations posed by ecosystem characteristics; (3) human value judgment and inevitable influence on forests should be considered. Moreover, the definition implies that a healthy forest can be described by many standards. A single forest condition could be viewed as healthy from one perspective or use and as unhealthy from another. For example, sanitation cutting is to clean out rotten and dead wood, stand, and flourish shrubs in forest. It is benefit for the growth of reserved tree that has high economical value and can decrease the feasibility of large-area fire. However, for the biodiversity in forest ecosystem, sanitation cutting is a heavy and direct destruction, at the same time, many ecological processes (nutrient decomposition and material cycling process) is disturbed and interdicted. Thus forest managers must have the explicit management objectives in order to decide which aspect is more important in terms of timber production, protection of biodiversity, and ecological process. By the confirmation of preferential objective, managers can avoid the confusion of multi-objectives. In 1999, Chinese government implemented "Natural Forest Protection Project", which claimed to stop the timber production in the natural forest and took the preservation of biodiversity and ecological integrity as the main objective in China. This is a best example for ecological environment.

Forest ecosystem function: This opinion is obviously different from the foregoing viewpoints. This understanding does not concern wood fiber at first, but emphasizes the basic ecological processes that create and maintain forest conditions to potentially satisfy with a range of diverse objectives as follows: "a forest in good health is a fully functioning community of plants and animals and their physical environment", "a healthy forest is an ecosystem in balance". Some other ecosystem definitions include the idea of resilience: "a healthy forest is one that is resilient to changes"; "the term of forest ecosystem health denotes the productivity of forest ecosystems and their ability to bounce back after stress" or "forest health can be defined as the ability of a forest to recover from natural and human caused stressors"(Kolb 1994; O'-Laughlin-J 1993). These definitions use the concrete ecosystem term, ecological properties, balance, functioning, and resilience, etc. to reflect the complicated relations within forest ecosystem and to make an annotation for the connotations of forest ecosystem health.

There are some doubts about these definitions. These definitions only emphasize some or certain aspects of ecosystem property. However, an ecosystem not only is composed of some entities such as plants, animals, soils, and water, but also includes the ecological process (energy capturing and transportation, nutrient supplying and cycling, disturbing, etc.). A healthy ecosystem robustly performs valuable ecological process and functions. Thus, a comprehensive definition of forest ecosystem health was discussed by many scholars (Callicott 2000; Costanza 1992; Kolb *et al.* 1994). They integrated with balance, resilience, and function of ecosystem to define forest ecosystem health. For example, in case of no damnification on energy flow and material cycle in ecosystem, on reservation of key ecological components (wild animals, soil, and micro fauna), and on resistance and resilience of natural disturbances, such a forest is considered as a healthy ecosystem. The followed questions are: How is the ecosystem in balance? What does the fully functioning mean? How to measure the degree of resilience and the level of resistance? In this case, the definition is still difficult to be used into practice. Unmeasured health cannot be used to esti-

mate its condition or to establish correlative management measures according to this definition.

Integrated perspective: The conflict between foregoing two understandings of forest ecosystem health is that the physical environment of forest ecosystem, maintained by itself, becomes a resource, an alluring resource for human-being. To achieve an applied, effective, and operational definition of forest ecosystem health, we should consider synthetically the property of forest, its social value, and our management objectives as well. O'Laughlin (1994) considered that forest ecosystem health is a condition of forest ecosystems that sustains their complexity while providing human needs. Complexity contains various properties of ecosystem, particularly; we should consider temporal-spatial settings that are reflected in the forest diversity. In the absence of detailed and quantitative information on desired rates of forest ecosystem process, the present definitions of forest health from ecosystem perspective must at least include a qualitative statement on the types of the process, structure, and resources that are needed to support productive forests in the sense of satisfying with at least some objectives of society. T.E. Kolb (1994) considered that a healthy forest ecosystem should have the following characteristics: (1) the physical environment, biotic resources, and trophic networks to support productive forests during at least some seral stages; (2) resistance to catastrophic change and/or the ability to recover from catastrophic change at the landscape level; (3) a functional equilibrium between supply and demand of essential resources (water, nutrients, light, growing space) for major portions of the vegetation; and (4) a diversity of seral stages and stand structure that provide habitat for many native species and all essential ecosystem process.

Based on the synthetic considerations of the property of nature, value trends, social and economics factors, and people's cognition level of ecosystem, we hold that forest ecosystem health is a capability or a condition of ecosystems that ensures their well-balanced ecological services and sustains their complexity and development while providing for human needs, maybe, for a stressed ecosystem, health is a goal, an ideal point that need to restore.

Connotation understanding of forest ecosystem health

In summary, entirely and fully understanding the connotations of forest ecosystem health needs some definitudes for ideas: compound property of forest ecosystem, hierarchy patch dynamics paradigm (Wu 2000), temporal-spatial scale, and concretely researching on concrete objects.

An ecosystem not only simply includes the biology, environments, and their inter-actions, but also includes the social, economic, and macro-policy factors, in terms of compound property of ecosystem. Forest ecosystem health synthesizes the bio-physical process, chemical process, and social dynamic. The two former drives forest ecosystem dynamical change, and the later decides its social value and expectation. Forest health and forest development are the basis of sustainable forest, and the healthy components, structure, functions, and dynamic form the basic characteristics of sustainable forest. A healthy forest ecosystem does not only means ecological health, but also the conditions propitious to the development of social economy and the benefit to health of human beings. Therefore, scholars manage to discuss the ecosystem health in the framework of sustainable development, which is the main rootstock to create a comprehensive definition.

Hierarchy patch dynamic paradigm, which was arisen in 1990s, explained the characteristics of ecosystem in an all-new standpoint. It stressed the disturbance, heterogeneity, and multi-scale as well as their effects on ecosystem management and preservation of nature (Wu 2000). The concept of forest ecosystem health root in a direct analogy of health of human, but we cannot cognize them by simple scaling. There are concrete differences between the health of an individual and that of a whole ecosystem. Some confusion in ecological scales leads to *ex parte* and inexplicit concept of health. The health of a tree is not equal to that of a stand, or directly analogizing. Diseased, withered, and rotten trees may be admissive in a stand, although they are not healthy themselves. For the health of a stand more aspects should be considered based on the management objectives and the long-time functions of network. The death rates of tree should be lower than the capability of self-regeneration in a stand. Furthermore, the health of a forest landscape, or a forest ecosystem, is more complex. The heterogeneity pattern caused by disturbances, particularly distinguished natural and/or man-made disturbances, incarnates a dynamic process of forest development, which causes a certain stress on forest; hence, unilateralism cannot appear while thinking of the health of forest ecosystem.

The complexity of forest ecosystem includes both the temporal scale and the spatial scale, furthermore, it relates to the various vegetation characteristics and ecological process under seral process. For various components in forest ecosystem, perhaps, some are in health and sustainability, but others are not. There are many balance states that can be inter-substituted in a dynamical ecosystem. These balance states are self-maintenance and can keep the functional integrity of ecosystem. In various organizational levels of a forest ecosystem, the interactions between species are unstable, nonequilibrium, even chaos (non-order), and usually restrained by the delay response of a large system. The incunabular evidences of environment stresses usually occur in the population level, particularly for the sensitive species, which should be considered in the monitoring and estimating for forest ecosystem health.

Conclusion and discussion

The conflict lying in different understandings on forest ecosystem health is resulted from that the physical environment maintained by forest ecosystem itself becomes a resource, an alluring resource for human.

To achieve an applied, effective, and operational definition of forest ecosystem health, the property of forest, social value, and management objectives (human need) should be considered synthetically. Based on the comprehensive considerations of property of nature, value trends, social and economics factors, and people's cognition level of ecosystem, we consider that forest ecosystem health is a capability or condition of ecosystems that ensures their well-balanced ecological services and sustains their complexity and development while providing for human needs; maybe, for the stressed ecosystems, health is a goal, an ideal point that needs to restore.

Different approaches in consideration of forest ecosystem health lead to the different concerns on study of health. Utilitarian perspective (objective-oriented approach) firstly cares about the wood productivity and makes emphasis on stand density, fire's intensity and frequency. However, from an ecosystem perspective, forest ecological process and effects of disturbance (cutting etc.) on ecosystem are the primary. The third approach, the comprehensive perspective has more thinking on sustainable index of forest ecosystem health on forest resources.

Now, the pith of healthy ecosystem is healthy structure and healthy function of ecosystem. In order to understand the structure and function of ecosystems, it is necessary to learn its origin, succession, process, characteristic and law of development, and the reciprocal mechanism between environment and ecosystem (Steedman 1994). Thus, the basic research of forest ecosystem is still the key for the research of ecosystem health. It is obvious that environment worsening by society development unilaterally established in economy benefits makes a rapid decrease of global forest covers and severe fragmentation of forest ecosystems. The decreasing of environment quality directly threatens the life quality and health status of human beings. Thus, we need much work on forest ecosystem health and long-term monitoring in forest to add the understandings on forest perspectives.

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